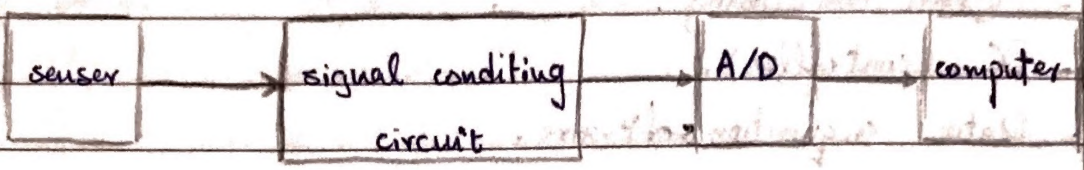
2018 / 3 / 15 1st lecture

Data acquisition

تعني تحصيل واستخلاص البيانات



for TLL

	0	1
which means	0V	5V
from the range	(0 ~ 0.8)V	(2 ~ 5.5)V

for CMOS

	0	1
from the range	0V	3 ~ 18V

2018 / 3 / 19

2nd lecture

Fundamentals of Data acquisition

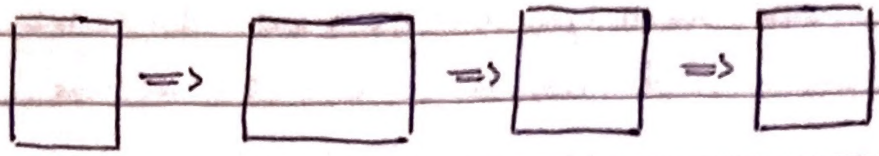
- Senser and transducer.
- Field wiring.
- Signal conditining.
- PC (controller).
- Data acquisition software.

اهم المصطلحات :

- المدى "Range"
- "Span"
- الحساسية "Sensitivity" ، "scale factor" ، "transfer function"

* Text book : Process control Instrumentation Technology
by : Curtis D. jhonson

2018 / 3 / 22 3^{rd} lecture

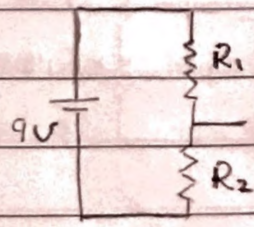


senser | signal conditining | A/D | computer

For good design

- choose avilible Power supply (1.5, 4.5, 9, 6, 12) V.
- choose avilible Resistance with suitble Power (w).

Ex:



find the value of Resistance R_1 & R_2 to make $v_o = 0.6$

يستطيع تحمل $(10 \sim 20)$ mA

from the voltage divider rule $v_o = v_s \dfrac{R_2}{R_1 + R_2}$

$$0.6 = 9 \cdot \frac{R_2}{R_1 + R_2}$$

$$0.6 R_1 = (9 - 0.6) R_2 \Rightarrow R_1 = 14 R_2$$

Note نستعمل الـ Bridge لأنه يمكننا التحكم عل range
يبدأ من الصفر ، بالإضافة إلى انه يعتبر محول بالأساس
من OHM لل voltage

2018/3/26 4th lecture

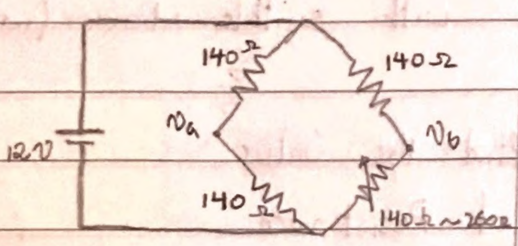
Ex: RTD with sensitivity $1.5\,\Omega/^\circ C$ and it's value at $0^\circ C = 140\,\Omega$, find the range $(0 \sim 80^\circ)$ in ohm, desing circuit to convert the range to volt

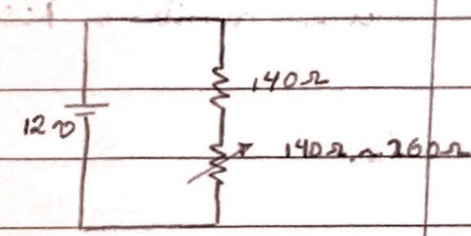
Sol :

$$260$$

the range From 140Ω to $(140 + 1.5 * 80)\,\Omega$

Whenstan Bridge | **Voltage divider**





Voltage Range from (0V ~ -1.8 V)

Voltage Range from (6V ~ 7.8 V)

$\Delta v = v_a - v_b$; $v_a = 6V$

at RTD = 140Ω & $v_b = 6V$

$\Delta v = 0V$

at RTD = 260Ω ; $v_b = 7.8V$

$\Delta v = -1.8V$

Nulling equation $R_1 R_4 = R_2 R_3$

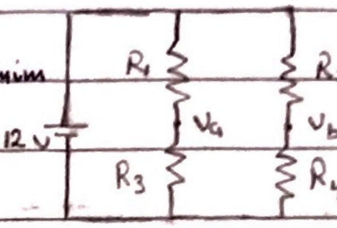
Ex: using the resistance 130 Ω, 270 Ω using the RTD with sensitivity 1.5 Ω/°C it's value at 0°C = 140 Ω, design circuit to convert the range in voltage.

sol

use 130 Ω for R_1 & 270 Ω for R_2 and RTD for R_4

from the nulling equation

$R_3 = \frac{R_1 R_4}{R_2}$; where R_4 at minimum



$R_3 = 67.4074\ \Omega$

at $R_4 = 140\ \Omega$; $V_a = 4.09$ volt , $V_b = 4.09$ V $\Delta V = 0$ V

at $R_4 = 260\ \Omega$; $V_a = 4.09$ V , $V_b = 5.88$ V $\Delta V = 1.79$ V

the Range in Voltage $(0 \sim 1.79)$ V

Ex: Pressure sensor sensitivity 0.09 V/bar and its value at 0 bar −0.2 V, Determine it output range for the Pressure $(0 \sim 140)$ bar, Design signal conditioning circuit for A/D circuit referance $(0 \sim 5)$ V

Sol : 12.4

the output range in volt from −0.2 V to $(-0.2 + 140 * 0.09)$ V

لإيجاد معادلة تربط بين v_i و v_o لتطابق ال A/D referance

$0 = -0.2\, M + \text{offset}$

$5 = 12.4\, M + \text{offset}$; $M = 0.3968$, offset $= 0.07936$

$v_o = 0.3968\, v_i + 0.07936$

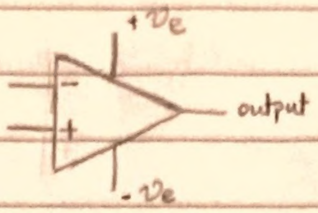
نقوم بالتحقق عن طريقة الجدول كالاتي

v_i	-0.2	6.1	12.4	
v_{out}	0	2.5	5	=> should be result
	0	2.499	4.999	=> the number from the equation

اخترنا 6.1 لانها في المنتصف بين 12.4 و -0.2

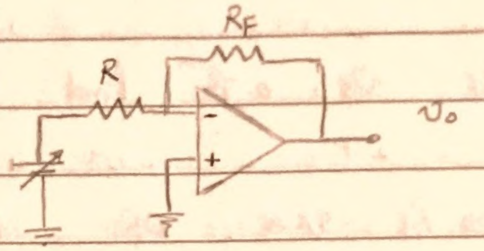
2018 / 3 / 29

5th lecture



±15 it's means that the different between the inputs can be up to 30 volt

- inverting amplifier



عيبه أنه يعطي gain بالسالب

$$\frac{V_o}{V_i} = -\frac{R_f}{R}$$

Ex: if signals $V_s = 0.8\,v$, find $(3S, \frac{S}{2}, 2.5S)$

1. $R_f = 3R$ $\quad V_o = -3 * 0.8 = -2.4$

let $R_1 = 1k\Omega$

$R_f = 3k\Omega$

2. $R_f = \frac{1}{2} R_1$ $\quad V_o = -\frac{1}{2} * 0.8 = -0.4$

let $R_1 = 1k\Omega$

$R_f = 500\,\Omega$

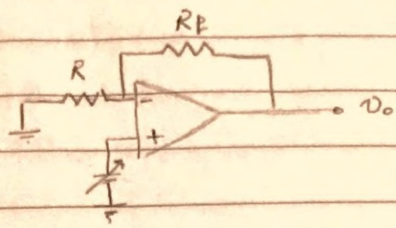
3. $R_f = 2.5 R_1$ $\quad V_o = -2.5 * 0.8 = -2$

let $R_1 = 1k\Omega$

$R_f = 2.5k\Omega$

لتخلص من ال gain السالب نقوم بعمل amplifier اخرى لإلغاء السالب

non-inverting amplifier



$$\frac{v_o}{v_i} = 1 + \frac{R_f}{R}$$

Ex: iF signals $v_s = 0.75$ find 5S

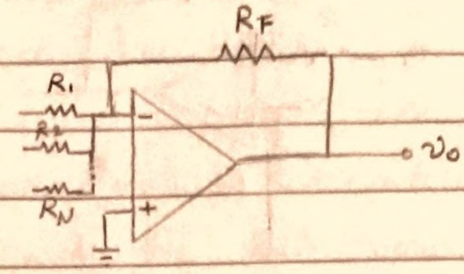
$R_1 = 1k\Omega$ So $R_f = 4k\Omega$ OR $R_1 = 3k\Omega$ So $R_F = 12k\Omega$

$v_o = (1 + 4)\, v_s = 3.75$ volt

بسبب وجود ال 1 + في القانون

2018/4/12 6th lecture

Summing Amplifier



$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \cdots \frac{R_f}{R_N} v_N\right)$$

Ex: $V_1 = 1.25$ volt, $V_2 = 0.67$ volt, $V_3 = 0.8$ volt

find $V_1 + V_2$, $V_1 + 2V_2$, $\frac{1}{2}V_1 + 2V_2 + 0.2V_3$, The average of them

1

$R_1 = 1k\,\Omega$

$R_2 = 1k\,\Omega$

$R_F = 1k\,\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2$

$v_o = 1.92$ volt

2

$R_1 = 1k\,\Omega$

$R_2 = 500\,\Omega$

$R_f = 1k\,\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2$

$v_o = 1.585$ volt

3

$R_1 = 500\,\Omega$

$R_2 = 2k\,\Omega$

$R_3 = 5k\,\Omega$

$R_F = 1k\,\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_F}{R_3} v_3$

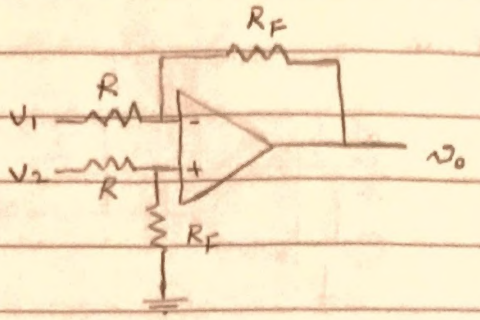
$v_o = 2.125$ volt

to find the average make the gain $\frac{1}{N}$

N: number of them

Note: to find $V_1 - V_2$ without mines make $V_2 - V_1$

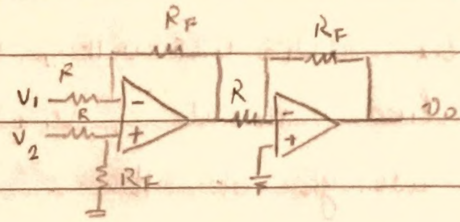
subtructor amplifier



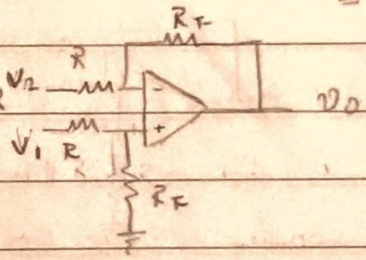
$$v_o = -\frac{R_F}{R}(V_1 - V_2) = \frac{R_F}{R}(V_2 - V_1)$$

Ex : if $V_1 = 1.25$ volt , $V_2 = 0.87$ volt find $V_1 - V_2$, $V_2 - V_1$

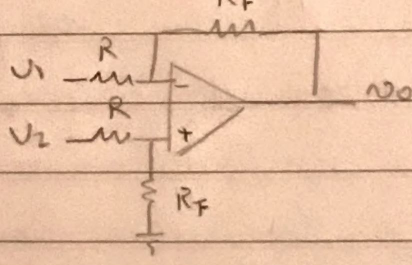
make $R_F = R$ to find $V_1 - V_2$



OR



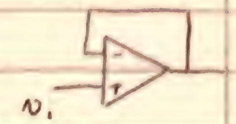
to find $V_2 - V_1$



$R_F = R$

Buffer

we use it to spert between the stages and make more fan out



Ex: using RTD with sensivity $1.5\ \Omega/^\circ C$ in the temperature range $(20^\circ \sim 80^\circ)$ and the RTD value at $0^\circ C = 120\ \Omega$,

- calculate its range in ohm & volt.
- Design circuit to convert the range into volt (using the Bridge)
- Design signal conditioning circuit to use $(0 \sim 5)$ ADC

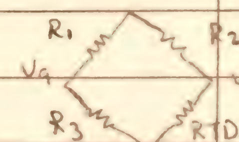
Solution:

at minimum 20° RTD $= 120 + 1.5 * 20 = 150\ \Omega$

at maximum 80° RTD $= 120 + 1.5 * 80 = 240\ \Omega$

so let $R_1, R_2, R_3 = 150$

and the power supply 9V



$$V_a = 9 \times \frac{150}{300} = 4.5 \text{ volt}$$

at nulling $$V_b = 9 \times \frac{150}{300} = 4.5 \text{ Volt}$$

$\Delta V = 0$ Volt

at maximum $$V_b = 9 \times \frac{240}{150 + 240} = 5.53846 \text{ Volt}$$

$\Delta V = -1.03846$

Range in ohm $(150 \sim 240)\ \Omega$

Range in volt $(0 \sim 1.038)$ Volt

to find the signal conditioning circuit

$0 = M * 0 + offset$

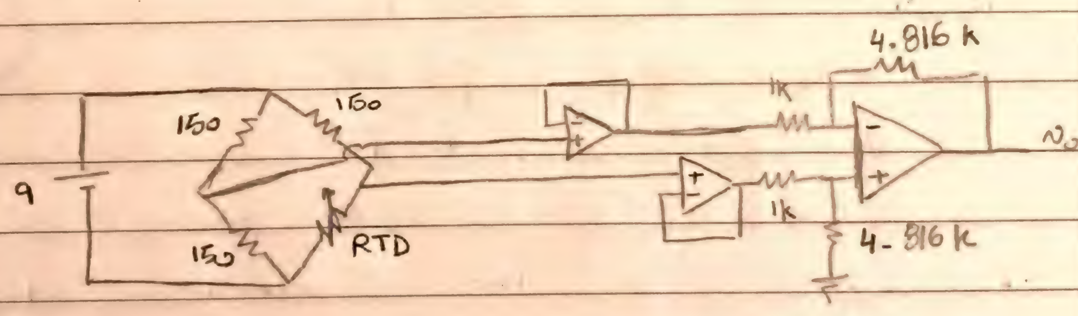
$5 = M * 1.038 + offset$

$M = 4.81695$ offset $= 0$

Vin	0	0.5016	1.038	جدول التحقيق
Vout	0	2.5	5	=> should be result
Vout	0.004μ	2.416	5.002	from computer Lab

using RTD = 187.635 for $\Delta V = 0.5016$

$$v_o = 4.816(v_b - v_a)$$



$$v_o = -\frac{R_F}{R}(v_a - v_b)$$

$$v_o = -\frac{4.816}{1}(v_a - v_b) = 4.816(v_b - v_a).$$

2018/4/5 7^{th} lecture

Ex: using RTD with sensitivity $0.39\ \Omega/C^{\circ}$ in the range $(0^{\circ} \sim 100^{\circ})$, RTD = $170\ \Omega$ at $0^{\circ}C$, use 9V supply, the two resistance $140\ \Omega$ & $180\ \Omega$ (using bridge)

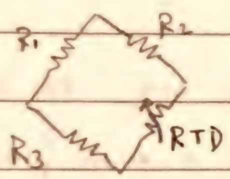
- Calculat the range in ohm & volt
- Desgin signal conditioing circuit to $(0 \sim 4V)$ reference ADC

solution :

at minimum RTD = 170

at maximum RTD = $170 + 0.39 * 100 = 209$

Range in ohm $(170 \sim 209)\ \Omega$



let $R_1 = 140$, $R_2 = 180\ \Omega$ RTD = 170

so $R_3 = \frac{R_1 R_4}{R_2} = 132.22\ \Omega$

$$V_a = 9 \times \frac{R_3}{R_1 + R_3} = 4.371\ V$$

at minimum $V_b = 9 \times \frac{170}{170 + R_2} = 4.371\ V$, $\Delta V = 0$ volt

at maximum $V_b = 9 \times \frac{209}{209 + R_2} = 4.835\ V$, $\Delta V = 0.464\ V$

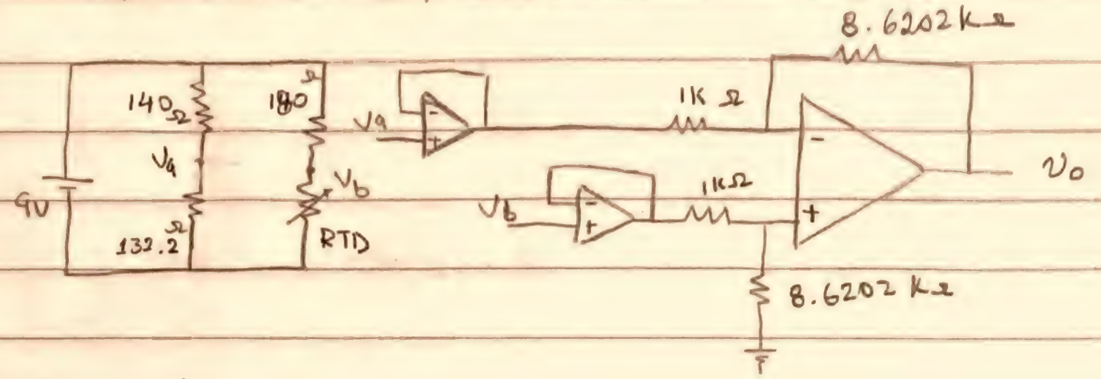
Range in Volt $(0 \sim 0.464)$ volt

for the signal conditioning circuit

$0 = M * 0 + offset$

$4 = M * 0.464 + offset$

$M = 8.6202$, $offset = 0$



$v_o = 8.6202 \, (V_b - V_a)$

Ex: Pressure sensor sensitivity 0.2 V/bar and its output at 0 bar = 0.8 V, calculate it's range in volt (in ± 10 bar)

- Design S.C. circuit for (0 ~ 3) voltage reference ADC

Soluation:

at minimum senser value $0.8 + 0.2 * -10 = -1.2$ Volt

at maximum senser value $0.8 + 0.2 * 10 = 2.8$ Volt

Range in volt $(-1.2 \sim 2.8)$ volt

for the S.C circuit

$0 = M * -1.2 + offset$ $\quad M = 0.75$

$3 = M * 2.8 + offset$ $\quad offset = 0.9$

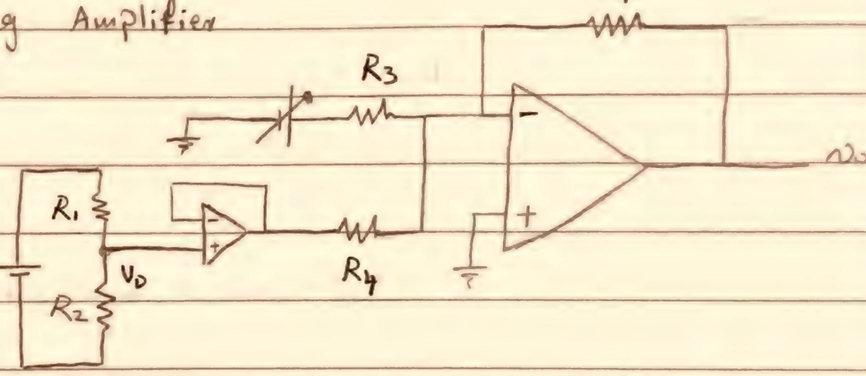
ملاحظات :

* عندما تكون بداية المدى سالبة نعوض بال offset موجب
"بالإضافة إلى أنه نتيجة ال offset تكون موجبة"
* عندما تكون بداية المدى موجبة و اكبر من صفر نعوض
بال offset سالب " كما أنه نتيجة ال offset تكون سالبة "
* في حالة " $V_o = M V_i + \text{offset}$ " نستخدم Summing Amplifier
* في حالة " $V_o = M V_i - \text{offset}$ " نستخدم Subtracter Amplifier
و نوصل ال offset من inverting therminal

Con. Solution :

$$V_o = 0.75\, V_i + 0.9$$

using Summing Amplifier



0.9

$$V_D = 9 \times \frac{R_2}{R_1 + R_2} \Rightarrow R_1 = 9 R_2$$

$R_4 = 0.75\,k\Omega$, $R_3 = 1k\Omega$, $R_F = 0.75\,k\Omega$, $R_1 = 9k\Omega$

$R_2 = 1k\Omega$

العلاقة بين $\frac{R_F}{R_3}$ يجب أن تساوي M , $\frac{R_F}{R_4}$ تساوي 1 حتى
يدخل ال offset كما هو
نتحصل على ال offset عن طريق مجزئ الجهد

* يجب إستخدام Buffer للفصل بين مجزئ الجهد و amplifier

Ex: Pressure senser sensitivity 0.31 V / bar and it output at 0 bar = -0.5 V.

- calculate its output in the range (± 12 bar).
- Design S.C. cct for (0~6) ADC voltage reference.

Solution:

minimum senser Output value -0.5 + 0.31 * -12 = -4.22 V

maximum senser Output value -0.5 + 0.31 * 12 = 3.22 V

Output range (-4.22 ~ 3.22) V

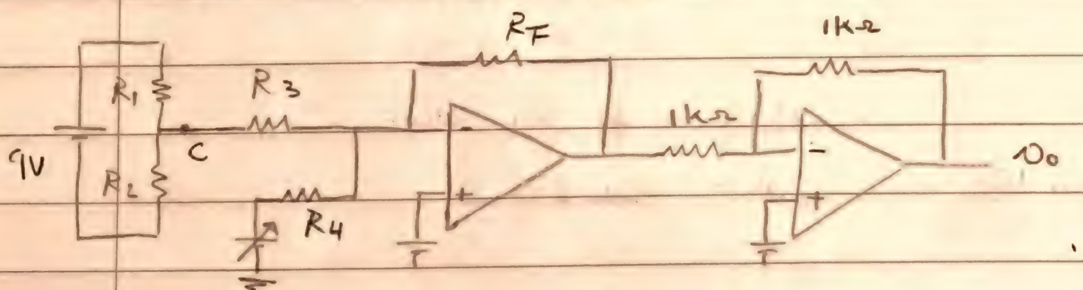
for S.C. cct

$0 = M * -4.22 + \text{offset}$

$6 = M * 3.22 + \text{offset}$

$M = 0.80645$ offset = 3.403

$v_o = 0.8064\, v_i + 3.403$



$\frac{R_F}{R_4} = 0.8064$ $R_F = 1k\Omega$ $R_4 = 1.24\,k\Omega$

$\frac{R_F}{R_3} = 1$ $R_3 = 1k\Omega$,   at point C = 3.403V

So $\underbrace{R_1 = 1.6447\, R_2}$ $R_1 = 1.64\,k\Omega$ $R_2 = 1k\Omega$

using voltage divider

Rule

2018 / 4 / 7 — 8^{th} lecture

Ex: Pressure Senser sensitinity 0.22 V/bar and it's output at 0 bar = 0.7 V

- calculate it output in the range (0 ~ 20) bar
- Design S.C. cct for (0 ~ 6) ADC

Soluation:

Output Range $(\underbrace{0.7}_{\text{minimum at 0 bar}} \sim \underbrace{0.7 + 0.22^* 20}_{5.1 \rightarrow \text{maximum at 20 bar}})$

for S.C. cct

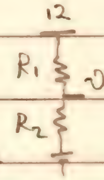
$0 = M^* \, 0.7 + \text{offset}$

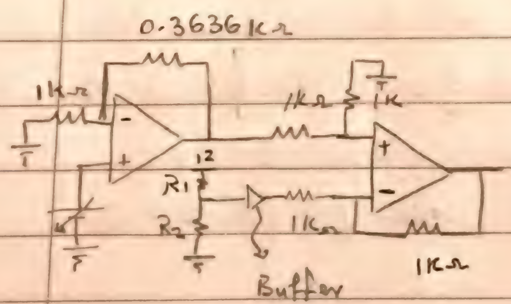
$6 = M^* \, 5.1 + \text{offset}$

$M = 1.3636$, offset $= -0.9545$

$V_o = 1.3636 \, V_i - 0.9545$

for the value of offset we can take it by the voltage divider Rule with supply 12 volt $R_1 = 11.572 \, R_2$





هناك ثلاثة طرق للحل

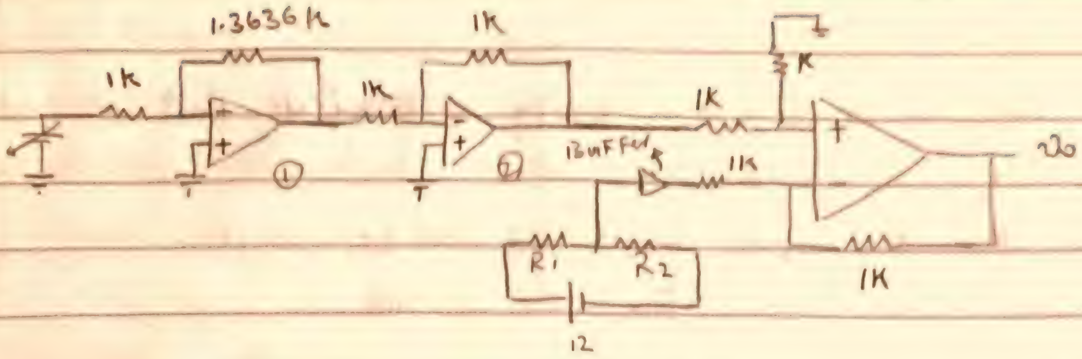
[I] هذه الطريقة تعتمد على الحصول على الـ gain الذي يجب ان يساوي M من non-inverting amplifier ثم ندخل M Vi على

الـ subtractor amplifier و يجب مراعاة معادلة الـ non-inverting amplifier $V_o = \left(1 + \frac{R_F}{R}\right) V_i$

لذا نقوم بطرح واحد من M للحصول على الـ gain المطلوب

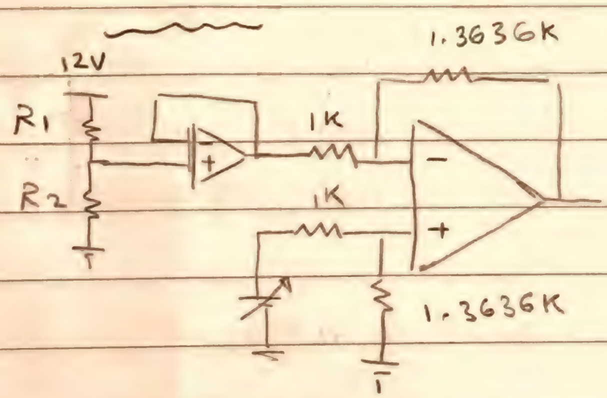
$$V_o = \left(\frac{0.3636}{1} + 1\right) V_{in}$$

[2]



في هذه الطريقة نستعمل inverting amplifier للحصول على الـ gain
لكن علينا مراعاة الإشارة السالبة $V_o = -\frac{R_F}{R} V_i$ لذا لنتخلص منها
نقوم بالضرب في gain اخرى بقيمة 1- وهو ما نتحصل عليه
من second amplifier ثم ندخلها لـ subtracter amplifier

[3]



في هذه الحالة نقوم باستعمال subtracter amplifier فقط ونقوم
بتغيير قيمة الـ offset لها يتناسب مع المعادلة

$$V_o = 1.3636\, V_i - 0.9545 = 1.3636\,(V_i - 0.6999)$$

حيث ندخل الـ offset بالقيمة 0.6999 وذلك عن طريق
تعديل المقاومة لتصبح $R_1 = 16.145\, R_2$

حيث $V_o = \frac{R_F}{R}(V_2 - V_1)$

ملحوظة هامة: كلما كانت الطريقة تعتمد على amplifiers أقل كلما كانت
أفضل ، لذا فالحل الثالث هو أفضل حل

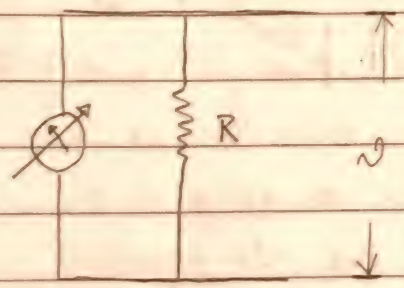
2018/4/12 9^{th} lecture

Ex: Accelerometer sensitivity 0.2 mA/g, calculate it's output range in ($\pm 10g$)
- Design signal conditioning circuit for ($0 \sim 3$) ADC

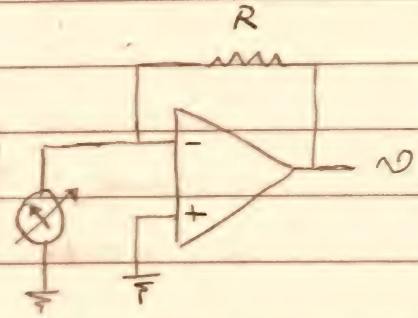
Solution:

Output Range in Amper $(\underbrace{0.2m * -10}_{-2m} \sim \underbrace{0.2m * 10}_{2m})$ Amp

to convert current to voltage there is two ways



$v = R.I$



$v = -RI$

في كلا الطريقتين يجب مراعاة قيمة المقاومة لانها ستتحكم بقيمة الـ Voltage Range

in case we choose $1K\Omega$
the Output Range in Volt
$(-2V \sim 2V)$

For example
$100K\Omega \Rightarrow \pm 200V$
$10K\Omega \Rightarrow \pm 20V$

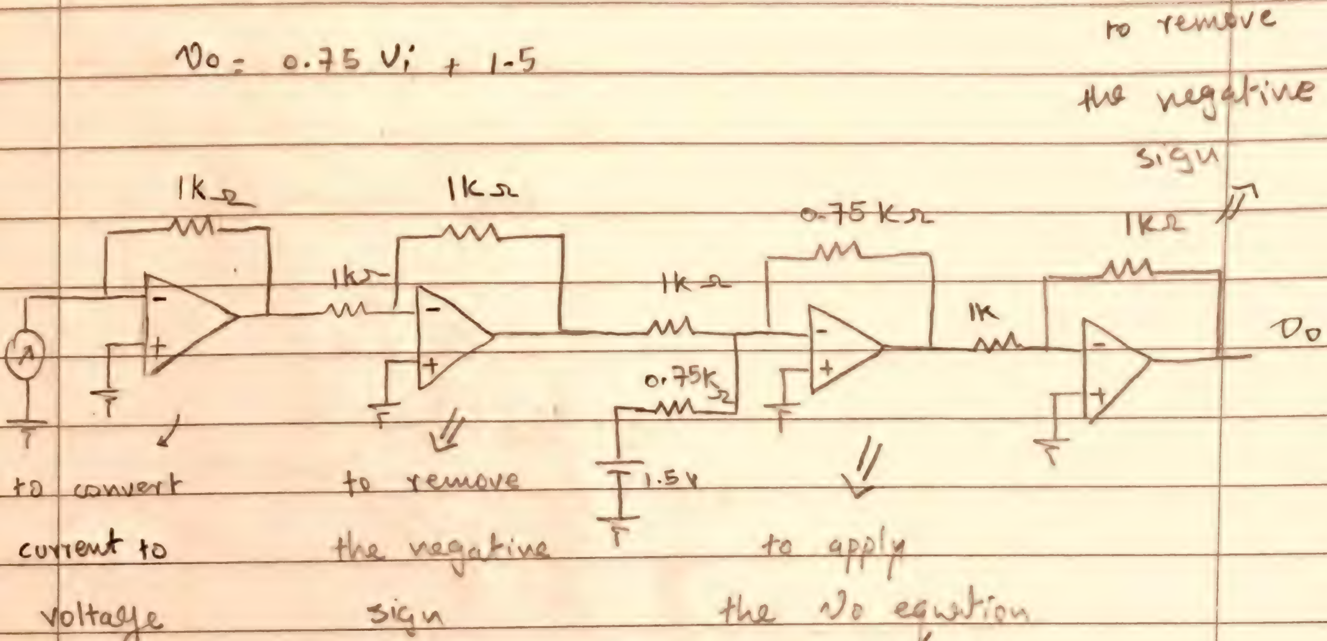
for S.C. cct

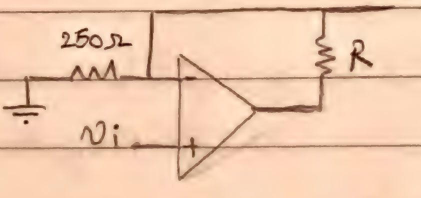
$0 = M * -2 + \text{offset}$

$3 = M * 2 + \text{offset}$

$M = 0.75$, $\text{offset} = 1.5$

$V_o = 0.75\, V_i + 1.5$





4mA ~ 20mA transmitter has current range 4mA ~ 20mA
Voltage range (1 ~ 5)V

* مدى التيار يبدأ من 4mA حتى نفرق بين المجس إذا كان معطوب أو لا حيث أن 0mA تعني ان المجس معطوب و 4mA تعني ان المجس يعمل

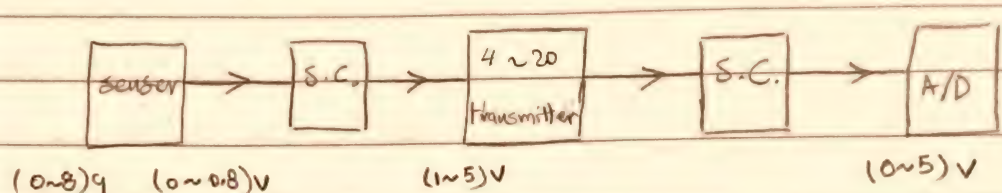
* يجب اختيار قيمة مقاومة صغيرة حتى يعمل بشكل صحيح

Ex: Accelerometer sensitivity 0.1 v/g for the range (0~8) g
we want to send Accelerometer data for 20 m to
use it for (0~5) ADC

Soluation:

0 0.8

Output range of the Accelerometer $(0.1 * 0 \sim 0.1 * 8)$ v



transmitter circuit

لأن T. cct تقبل المدى من 1V إلى 5V و A/D تحتاج المدى من 0V
إلى 5V سنجبر لإستعمال 2 S.C. الاولى لتصفية خرج المجس
ل T.cct و الأخرى لتصفية الاشارة لدخول ل A/D.

بالنسبة ل first S.C. سنقوم بزيادة 1 فقط ليصبح
المدى من 1V إلى 1.8V و هذا المدى يقبل به في T.cct

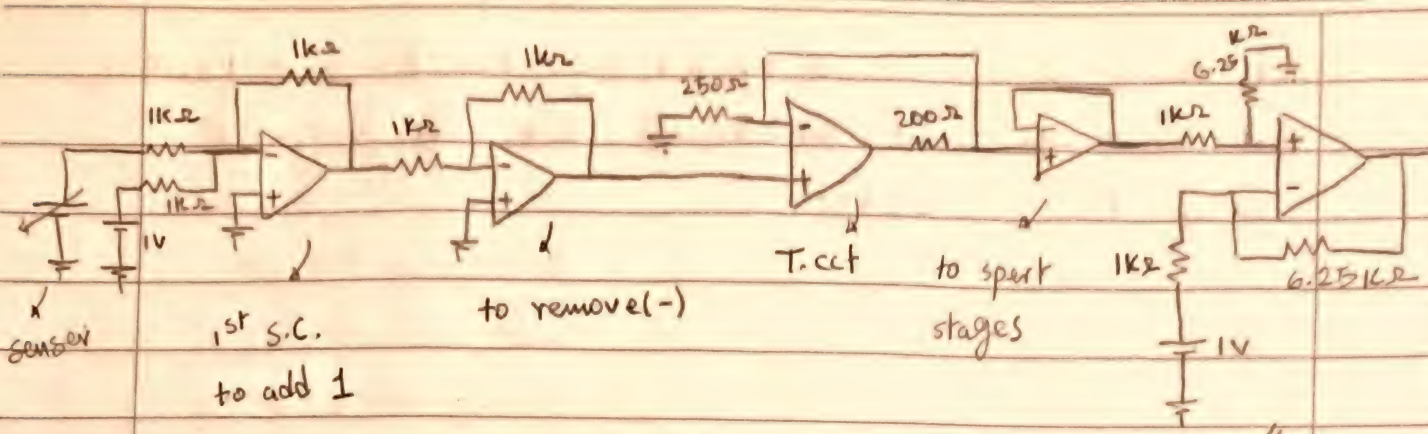
اما بالنسبة لـ second S.C. سنقوم باتباع الخطوات المعتادة

$0 = M * 1 + offset$

$5 = M * 1.8 + offset$

$M = 6.25$, $offset = -6.25$

$v_o = 6.25 v_i - 6.25$


1kΩ
1kΩ
1kΩ
1kΩ
1V
1kΩ
1kΩ
250Ω
200Ω
1kΩ
6.25 kΩ
1kΩ
6.25kΩ
1V
sensor
1st S.C.
to add 1
to remove(-)
T.cct
to spert stages

$v_o = 6.25(v_i - 1)$

2018/4/16 10th lecture

Ex: Temperature senser sinsitivity $0.2\ mV/C^\circ$ in the range $(0 \sim 100)^\circ C$ and it's output at $0^\circ C = 12\ mV$.

- Design S.C. circuit for $(0 \sim 8)$ ADC ...
- Write the temperature equation

Soluation:

Output Range $(12\ mV \sim \underbrace{12\ mV + 0.2m * 100}_{32\ mV})$

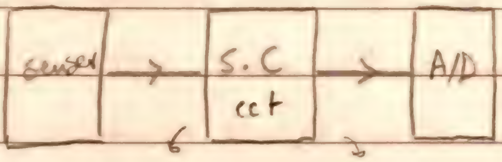
for S.C. cct

$0 = M * 12m + offset$

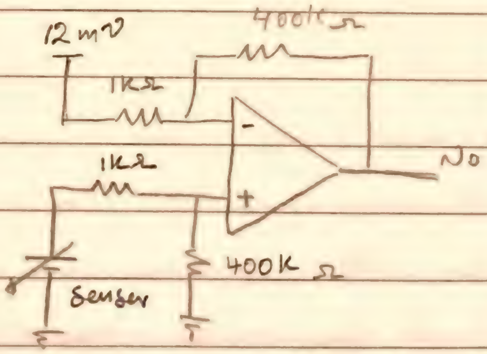
$8 = M * 32m + offset$

$M = 400$ offset $= -4.8$

$v_o = 400\, v_i - 4.8 = 400(v_i - 12m)$



$v_i = 12m + 0.2mT$ $v_o = 400(v_i - 12m)$



$v_o = 400(\cancel{12m} + 0.2mT - \cancel{12m})$

$v_o = 80mT \Rightarrow T = \dfrac{v_o}{80m}$

Ex: For the last example in the last lecture write acceleration equation.

$$\boxed{\text{Sensor}} \rightarrow \boxed{\text{S.C}} \rightarrow \boxed{\text{T.cct}} \rightarrow \boxed{\text{S.C}} \rightarrow \boxed{\text{A/D}}$$

$v_i = 0.1 * A$ $\quad v = v_i + 1$ $\quad v_o = 6.25\, v - 6.25$

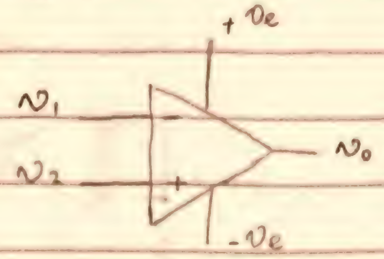
$$v_o = 6.25(v_i + 1) - 6.25 = 6.25(0.1\,A + 1) - 6.25$$

$$v_o = 6.25 * 0.1A + \cancel{6.25} - \cancel{6.25}$$

$$A = \frac{v_o}{0.625}$$

2018/4/19 11^{th} lecture

Comparator



when

$V_1 > V_2$

$V_o = -15$

$V_2 > V_1$

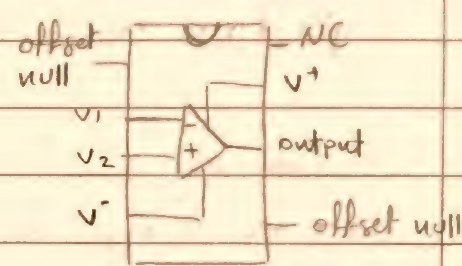
$V_o = 15$

LM 741 voltage supply

± 22 volt

± 18 volt

IC 8

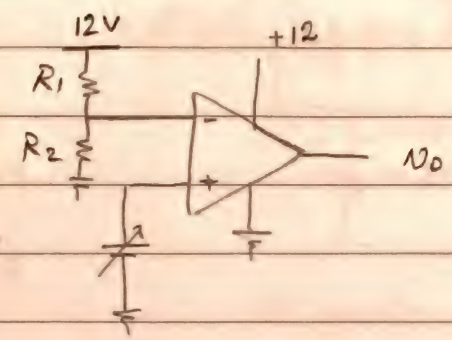


by using poltioumeter between offset null we can get zero offset

Ex: using comparator, Design circuit to operate Fan if the temperature is more than 25°C (use LM 35 sensitivity 10mV/°C)

Soluation

at 25°C the output of LM35 = 10m * 25 = 250mV

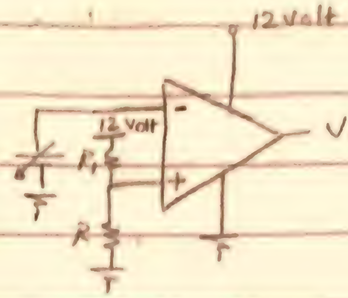


قمنا بتوصيل جهد ثابت عند ال
inverting input لانه في حالة تجاوز
ال non-inverting input هذا الجهد سيكون
خرج المقارن موجب مما يشغل
ال Fan

$R_1 = 47 R_2$

Ex: using comparator, Design circuit to operate Heater if the temperature is less than 18°c (Temp. sensor sensitivity 8mV/c)

Reference voltage 18 * 8m = 144 mV



نقوم بتوصيل الحساس بال V_1 لانه عندما تكون أقل من V_2 سيكون الخرج موجب "كأن V_2 اكبر من V_1"

$R_1 = 82.33\ R_2$

Ex: using compartor, Design circuit to operate Heater if temperature is less than 18°c and operate fan if temperature is more than 30°c (senser sensitivity 5mV/c)

Soluation

Reference voltage for 18°c = 90 mV

Reference voltage for 30° = 150 mV

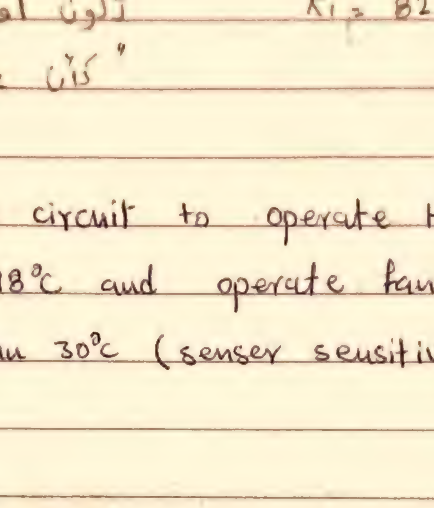
for 18°c

$R_1 = 132.3\ R_2$

for 30°C

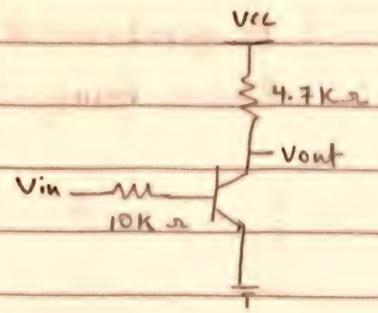
$R_3 = 79\ R_4$

to 12 voltage supply

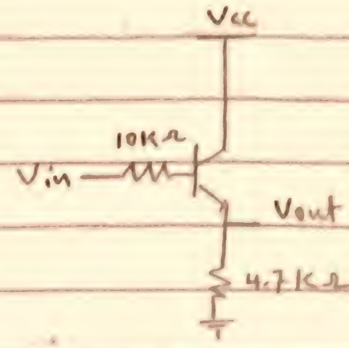


2018/4/23

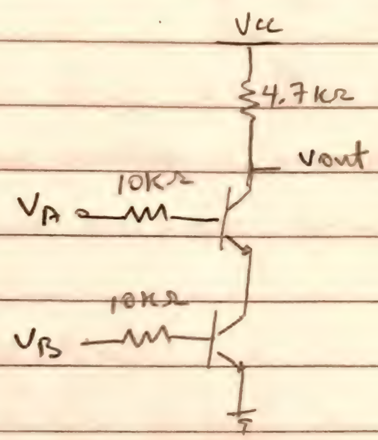
12th lecture



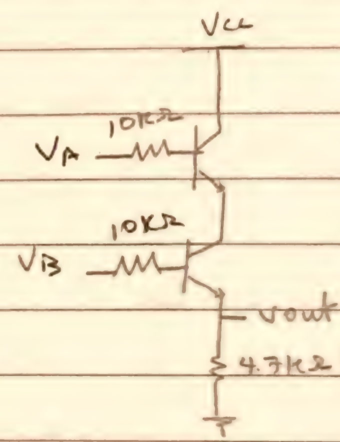
Not gate



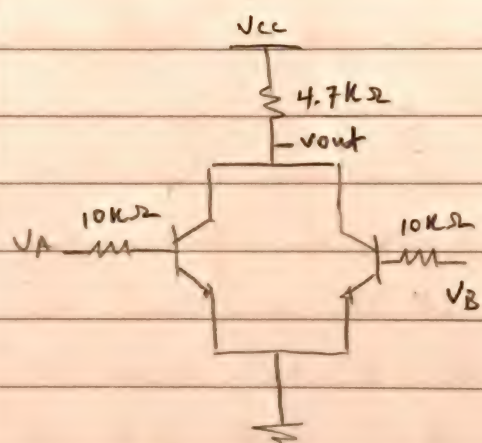
Buffer gate



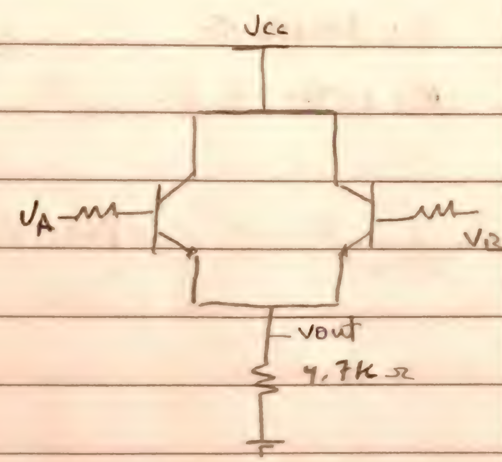
NAND gate



AND gate

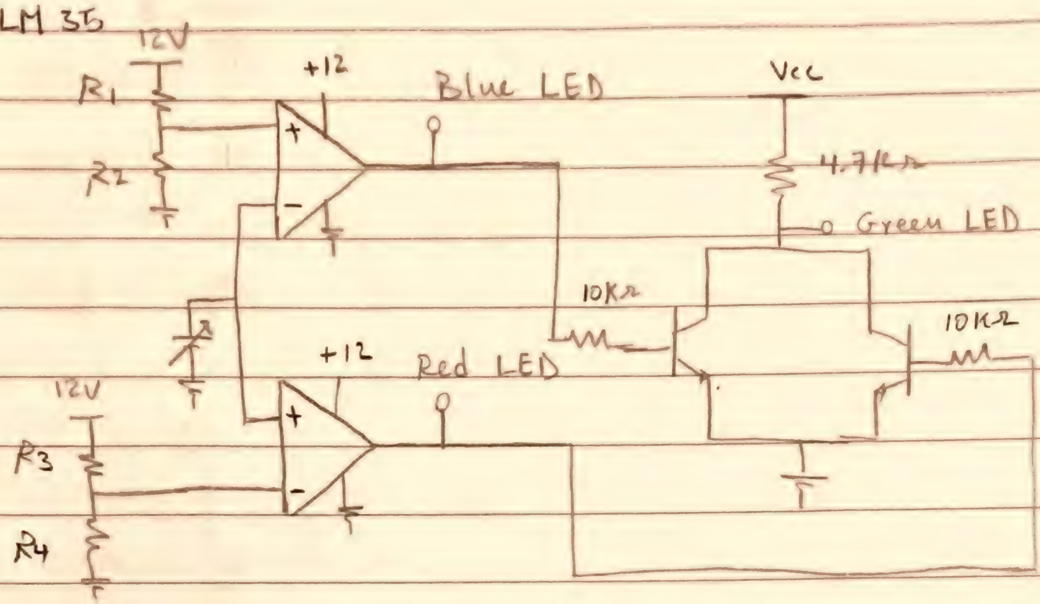


NOR gate



OR gate

Ex: Design circuit operate Red LED if Temperature is more than 37°C and operate blue LED if temperature is less than 15°C and Green LED in between using LM 35



Reference for 18°C = 180 mV

Reference for 37°C = 370 mV

for voltage supply 12 volt

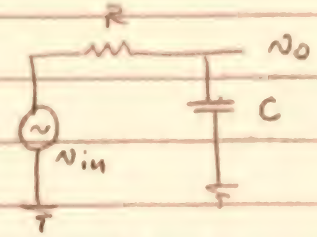
$R_1 = 65.67\ R_2$

$R_3 = 31.43\ R_2$

2018 / 4 / 26 13th lecture

Filters

Low Pass filter



$$f_c = \frac{1}{2\pi RC}$$

$$\frac{v_o}{v_i} = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$$

Ex: Design Filter to attenuate the noise to 1% and calculate the effect of the filter on the signal if the signal = 5V (1kHz) and the noise = 200mV (320kHz)

Soluation

$$1\% = \frac{1}{\sqrt{1+\left(\frac{320k}{f_c}\right)^2}} \Rightarrow f_c = 3.2\,kHz$$

the effect on the signal $\frac{1}{\sqrt{1+\frac{1k}{3.2k}}} = 95.4\%$

assume $C = 2.2\mu F$ so $R = 22.607\,\Omega$ $f_c = \frac{1}{2\pi RC}$

to small so we try another value

$C = 0.1\mu F$ so $R = 497.35\,\Omega$ dosen't a standard value

we take $510\,\Omega$ $f_c = 3.202\,kHz$

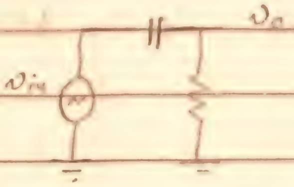
the effect on the noise became 1.00057%

* Filter make some delay

2018/5/14 14^{th} lecture

High Pass Filter

$$\frac{v_o}{v_i} = \frac{F_s/F_c}{\sqrt{1+\left(\frac{F_s}{F_c}\right)^2}}$$



Ex: Design filter to attenuate 50HZ noise signal from the required 4 KHZ signal.

Solution

if we want to attenuate the noise 1%

$$0.1\% = \frac{50/F_c}{\sqrt{1+\left(\frac{50}{F_c}\right)^2}} \Rightarrow F_c = 4.9\,KHZ$$

the attanuation on the required signal = 63.23%

this value is not good so we try another value

for 5% attenuated in the noise signal

$$5\% = \frac{50/F_c}{\sqrt{1+\left(\frac{50}{F_c}\right)^2}} \Rightarrow F_c = 998.7\,HZ$$

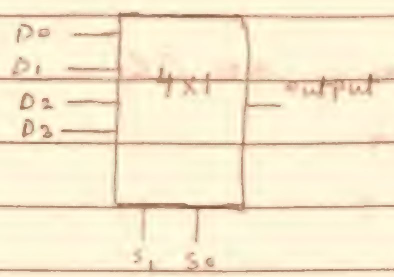
the attenuation on the required signal = 97.02%

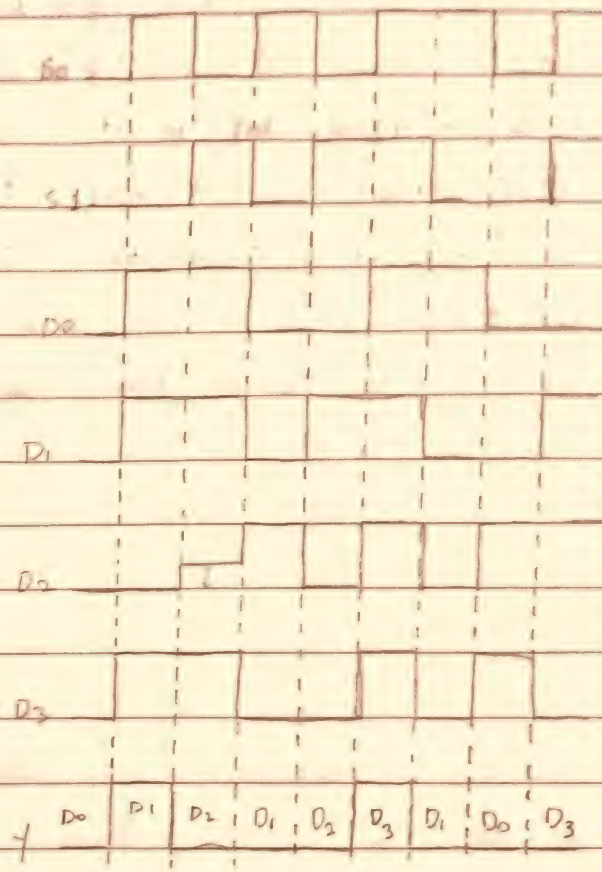
for 10% attenuate on the noise

$F_c = 497.4 Hz$

and the attenuation on the required signal = 99%.

* Multiplexer





ملاحظة: تتم تسمية Multiplexer
بعد الـ input و الـ output
ولا يتم ذكر الـ selection

Digital Mux

لماذا نستعمل الـ Multiplexer ؟

- يوفر .S.C. cct حيث أنه لو هناك أكثر من sensor من نفس النوع نقوم بتوصيلهم بالـ Multiplexer و الـ output ندخله كـ input للـ .S.C. cct

* Analogy to Digital converter

* Vin = Vm

* V_{re}^{+-} هو الحد الأدنى والأعلى للإشارة

مثلا unipoler (احادي القطبية): (0 ~ 5) أو (-5 ~ 0)

أو Bipoler (ثنائي القطبية): (± 2) أو (± 5)

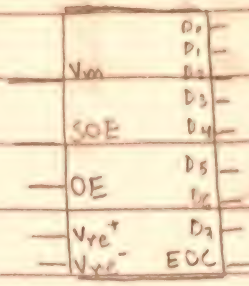
* SOC : امر بداية التحويل start of convention

* OE : إظهار البيانات Output Enable

* EOC : End of convention و هذا ال Flag

تتم مراقبته من قبل المعالج مراقبة شديدة

هل هو مشغول أو لا



8bit ADC

2018/5/17 15th lecture

+ Analog to Digital converter :

Resolution (ΔV) : أقل قيمة لدخل يستشعرها المحول لزيادة بمقدار 1 bit

$$\Delta V = \frac{\text{Voltage reference}}{2^N} = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^N}$$

حيث N : عدد المخارج

ملاحظة : كلما صغرت ΔV اصبح A/D أدق

Ex: unipoler Vref (10 ~ 0) with 4-bit output.

$$\Delta V = \frac{10-0}{2^4} = 0.625$$

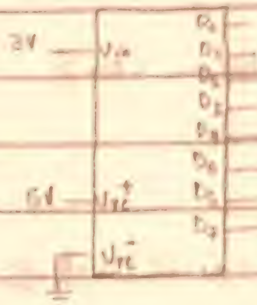
$$\text{Digital Output} = \frac{\text{Analog input}}{\Delta V} \Rightarrow \text{for unipoler}$$

Ex: if input 5V , 10V with the same A/D ، what is the Digital Output.

$$\text{Digital output} = \frac{\text{Analog input}}{\Delta V} = \frac{5}{0.625} = 8 = 1000$$

$$\text{Digital output} = \frac{10}{0.625} = 16$$ which is not valid value because the Maximum value 15

Ex: What is the output of the following ADC, and what is the analog input value if digital output is $(A7)_H$



Solution:

$\Delta V = \frac{5-0}{2^8} = 19.53\ mV.$

$\text{Digital output} = \frac{3}{19.53m} = 153.6 = 153 \pm 1$

$(10011001)_B$

$\text{Digital output } (A7)_H = (167)_{10}$

$\text{Analog input} = \text{Digital output} \cdot \Delta V = 3.26\ V$

Ex: temperature sensor sinstivity $0.8mV/C^\circ$ in the range $(0 \sim 60^\circ C)$ and it's output value at $0^\circ C = 0.75V$.
Design S.C.cct. for $(0 \sim 5)$ V ADC and what is the temperature final equation.

Solution:

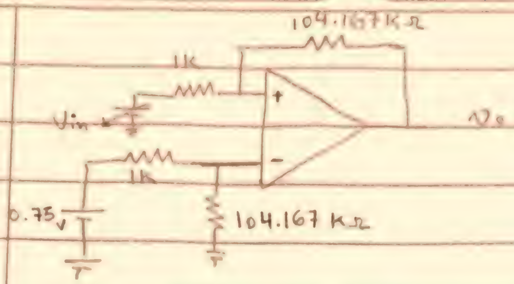
0.798

Output sensor range $(0.75 \sim 0.75 + 0.8m * 60)$

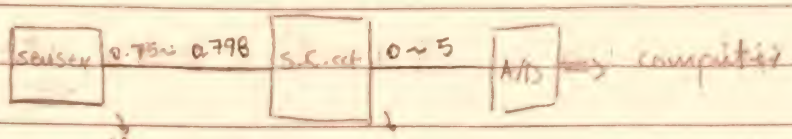
$0 = 0.75 * M + \text{offset}$ $\quad M = 104.1667$

$5 = 0.798 * M + \text{offset}$ $\quad \text{offset} = -78.125$

$V_o = 104.167\,V_i - 78.125 = V_o = 104.167\,(V_i - 0.75).$



Signal Conditionation circuit



v_i $= (0.75 + 0.8m\,T)$

v_0 $= 104.167(v_i - 0.75)$

Digital output $= \dfrac{v_0}{\Delta V}$

$$\text{Digital output} = \frac{v_0}{\Delta V} = \frac{104.167(v_i - 0.75)}{\Delta V} = \frac{104.167\,((\cancel{0.75} + 0.8m * T) - \cancel{0.75})}{\Delta V}$$

$$T = \frac{\text{Digital output} * \Delta V}{0.8\,m * 104.167}$$

2018/5/21

16th lecture

Analog to Digital "bipoler"

$$\Delta V = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^N}$$

$$\text{Digital Output} = \frac{\text{Analog input} + V_{ref}^{+}}{\Delta V} = \frac{\text{Analog input} - V_{ref}^{-}}{\Delta V}$$

Ex: for Bipoler ADC with Vref ± 3V, Vin 1.5V, 8-bit output what is the Digital output

$$\Delta V = \frac{3-(-3)}{2^8} = 23.4375 \text{ mV}$$

$$\text{Digital Output} = \frac{1.5+3}{23.4375m} = 192 \quad (1100\ 0000)_B$$

Ex: for Bipoler ADC with ±3V and 8bit Output what is the Digital output for the input 0V

$$\Delta V = \frac{3-(-3)}{2^8} = 23.4375 \text{ mV}$$

$$\text{Digital Output} = \frac{0+3}{\Delta V} = 128 \quad (1000\ 0000)_B$$

Ex: Using an accelerometer which sensitivity 10 mV/g in the range ± 20 g, Design S.C. cct. for ADC which reference ±5 V with 8-bit output, what is the ADC output at 3g, -7g, what is the acceleration equation for this circuit

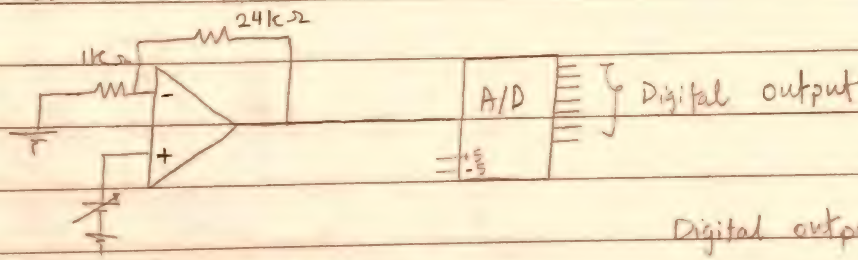
Soluation:

Sensor output range (-20 * 10 mV ~ 20 * 10 mV)
-200 mV ~ 200 mV

$-5 = -200\,m\, M + \text{offset}$ $\quad M = 25$

$5 = 200\,m\, M + \text{offset}$ $\quad \text{offset} = 0$

$V_o = 25\, V_i$



$$\text{Digital output} = \frac{\text{Analog} + 5}{\Delta V}$$

$$V_o = \left(1 + \frac{R_F}{R}\right) V_i$$

$$\Delta V = \frac{5-(-5)}{2^8} = 39.0625\ mV$$

Acceleration	3g	-7g
$V_i = A * 10m$	30 mV	-70 mV
V_o	0.75 V	-1.75 V
Digital output	147.2 ≈ 147	83.2 ≈ 83
	$(1001\ 0011)_B$	$(0101\ 0011)_B$

$$\boxed{\text{Sensor}} \xrightarrow[= Acc * 10m]{v_i} \boxed{\text{S.C. cct}} \xrightarrow[= 25 v_i]{v_o} \boxed{\text{A/D}} \xrightarrow{} \text{Digital output} = \frac{v_o + 5}{39.0625m}$$

$$\text{Digital output} = \frac{v_o + 5}{39.0625m} = \frac{25 v_i + 5}{39.0625m} = \frac{25 * 10m * Acc + 5}{39.0625m}$$

$$Acc = \frac{(\text{Digital output} * 39.0625m) - 5}{25 * 10\,m}$$

2018/5/24 17th lecture

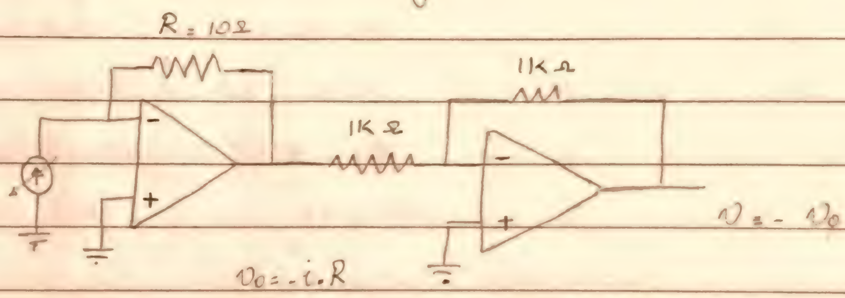
Ex: Using barometer which sensitivity 10mA/bar and it's output at zero bar is 25 mA, Design S.C. cct. for the range ±10 bar and using ADC (V_{ref} ±2V), what is the digital Output of ADC at -2bar, +3.5 bar, what is the pressure equation will using in the program.

Soluation:

-75 mA ~ 125 mA

Sensor Range Output (25 m + -10 x 10 m) ~ (25 m + 10 x 10 m)

first convent current to voltage



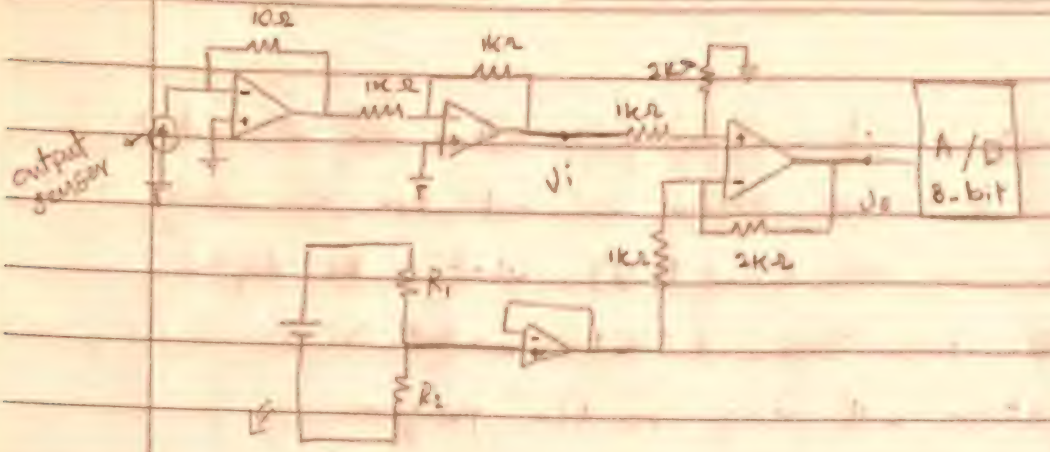
so the Output Range now will be (-0.75 ~ 1.25) V

then the S.C. cct

$-2 = -0.75\ M + \text{offset}$ $\quad M = 2$

$2 = 1.25\ M + \text{offset}$ $\quad \text{offset} = -0.5$

$V_o = 2V_i - 0.5 = 2(V_i - 0.25)$

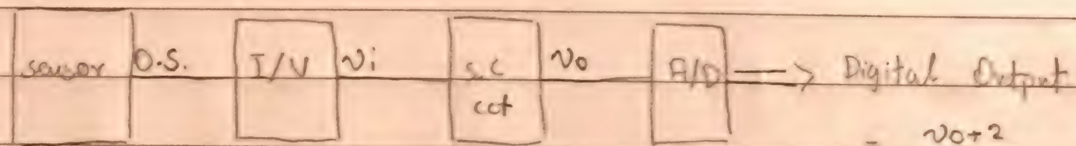


$$0.25 = 3 \times \frac{R_2}{R_1 + R_2} \Rightarrow R_1 = 11 R_2$$

Prusser	-2 bar	3.5 bar
Output sensor (25 m + 10 m * P)	5 mV	60 mV
v_i (O.S. * 10)	0.05 V	0.6 V
v_o (2 v_i - 0.5)	-0.4	0.7
Digital output ($\frac{v_o + 2}{\Delta V}$)	102.4 ≈ 102	172.8 ≈ 173
	$(0110\,0110)_B$	$(1010\,1101)_B$

$$\Delta V = \frac{2-(-2)}{2^8} = 15.625 \text{ mV}$$

Now the equation



$= \frac{v_o + 2}{\Delta V}$

$I = 25m + P * 10m$ $\quad v_i = 10 I$ $\quad v_o = 2v_i - 0.5$

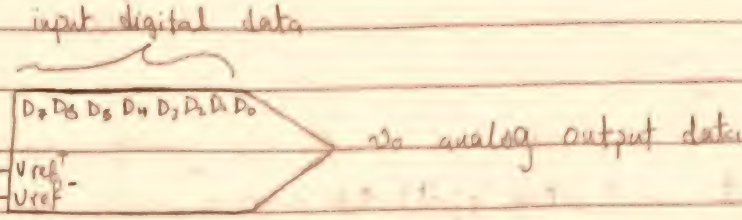
$$\text{Digital output} = \frac{v_o + 2}{\Delta V} = \frac{2v_i - 0.5 + 2}{\Delta V} = \frac{20I - 0.5 + 2}{\Delta V} =$$

$$= \frac{\cancel{0.5} + 0.2P - \cancel{0.5} + 2}{\Delta V}$$

$$P = \frac{\text{Digital Output} * \Delta V - 2}{0.2}$$

2018/3/28 18th lecture

* Digtal to analog (DAC)



For unipoler

$\Delta V = \frac{V_{ref}}{2^N}$ → number of input bits

analog output = Digital input * ΔV

Ex: what is the analog value of the Digital input $(01010101)_B$ with the Vref (0 ~ 4)

$(85)_D$

$\Delta V = \frac{4}{2^8} = 15.625\ mV$

Analog value = 85 * ΔV = 1.328 V

Ex: For the DAC with 8-bit input and Vref (0~4) what is the value of digital input if the analog value 2.35 V?

Digital input = $\frac{\text{Analog Output}}{\Delta V} = \frac{2.35}{15.625} = 150.4 \approx 150$

$(10010110)_B$

for bipolar

$$\Delta V = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^N}$$

Analog output = Digital input ΔV - V_{ref}^{+}

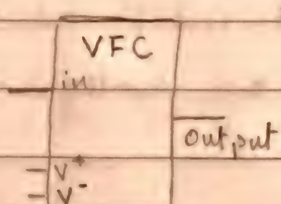
Ex: what is the analog value for DAC with 8-bit input and ± 3 Vref of the following 0111 0000, 0000 1100, 1010 0000

$$\Delta V = \frac{6}{2^8} = 23.4375 mV$$

Analog output = (ΔV * Digital input) - 3

Binary Digital input	01111 000	0000 1100	1010 0000
Decimal Digital input	120	12	160
Analog output	-0.1875	-2.71875	0.75

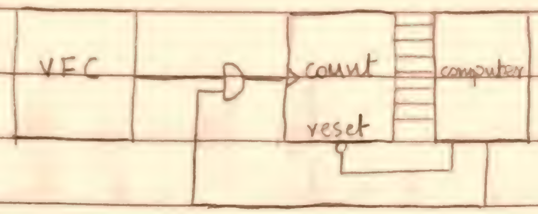
* Voltage to frequency converter (VFC)



the output is pulses

Ex: if VFC has 1KHz/V what is the output if the input 1.25 V

Output = $1.25\ V * 1KHz/V = 1250\ Hz$



نستعمل ال reset لتصفير ال counter لانه تراكمي يقوم بتجميع القراءات معاً" و لتحديد زمن الدورة الواحدة

Ex: if VFC has 1KHz/V with T = 0.25 and input 3V, what is the counter output?

VFC output = $3\ V \times 1KHz/V = 3000\ Hz$

counter output = $3000\ Hz * 0.2\ \frac{1}{Hz} = 600$

ملاحظة : البعض يعتقد أن هذه الدائرة هيا أفضل في التحويل من Analog إلى Digital

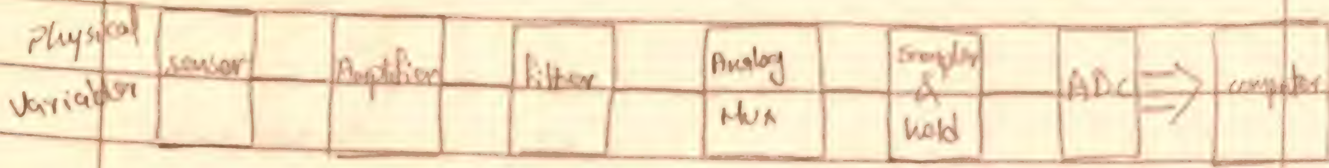
Ex: if counter output = 150 what is the input if T = 0.25 and VFC has 1KHz/V

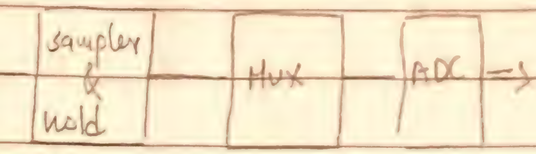
counter input = $\frac{150}{0.2} = 750\ Hz$

VFC input = $\frac{750\ Hz}{1000\ Hz/V} = 0.75$ Volt

2018 / 5 / 31 19th lecture

Data acquistion and conversion





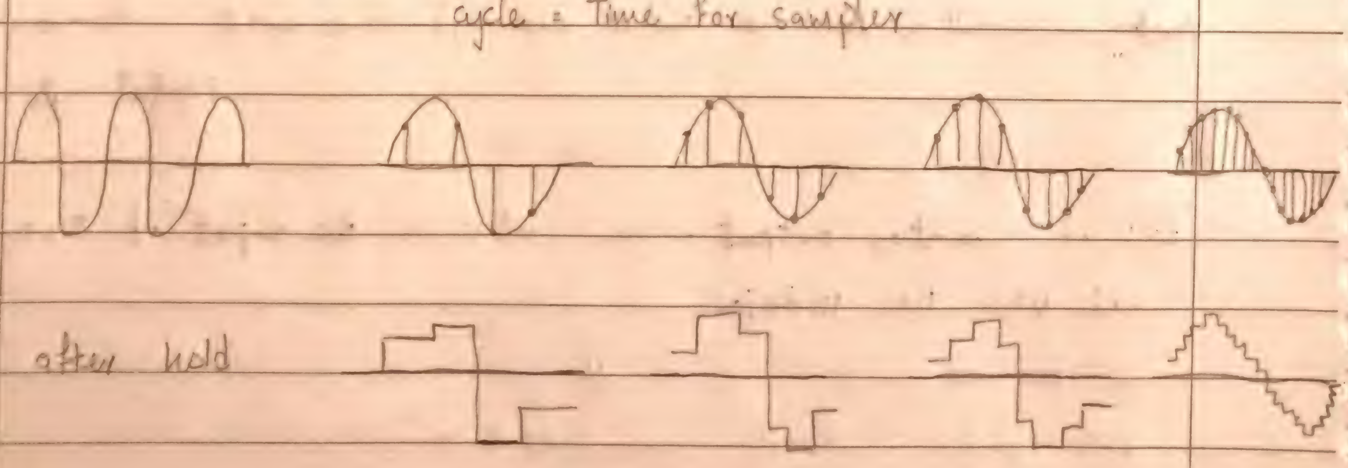
ADC conversion time : الزمن الذي يستغرقه ADC لتحويل

Sampler rate : معدل التحويل

↳ one of the most critical factors when selecting an bond sampling rate (speed), for example 1K sample.

The sampling rate is a measure of how rapidly the ADC Board can scan the input channel and identify the discrete value of signal present with respect to reference signal

cycle = Time for sampler



if the sampling rate is too slow, then a completly different waveform of lower frequency is constructed from the data recquired, this effect is called aliasing.
To avoid aliasing it's necessary that the sampler rate is be at least twice of the highest expected frequency input.

Over Sampling : will provide a true picture of time course of the eventbeing studied but too much over sampling will result in very large data file.

* Sensor :

Thermal sensors

Relative temperature Scale

$T(C^\circ) = T(K^\circ) - 273.15$

$T(F^\circ) = T(R^\circ) - 459.6$

$T(F^\circ) = \frac{9}{5} T(C^\circ) + 32$

R: Rankine , K: kelven , F: Fahrenhiet , C: Ceiac

Ex: Amatenal has temperature of $335^\circ K$ Find the temperature in R°

$T(C^\circ) = T(K^\circ) - 273.15 \Rightarrow T(C^\circ) = 61.85$

$T(F^\circ) = \frac{9}{5} T(C^\circ) + 32 \Rightarrow T(F^\circ) = 143.33$

$T(R^\circ) = T(F^\circ) + 459.6 \Rightarrow T(R^\circ) = 602.93$

2018/6/4

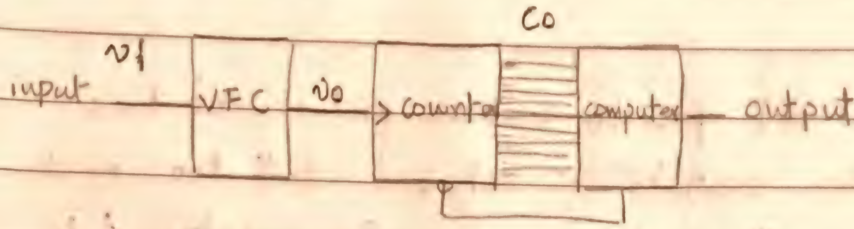
20 lecture

Examples:

if VFC has 5kHz/v and the reset time of the counter 0.02sec what is the output if

a) the input 1.25v

b) the input 2.43v



Soluation

a)

v_o = input * 5 KHZ/v = 6250 Hz

Co = v_o * T = 125

b v_o = 2.43 * 5k = 12150 Hz

Co = 12150 * 0.02 = 243

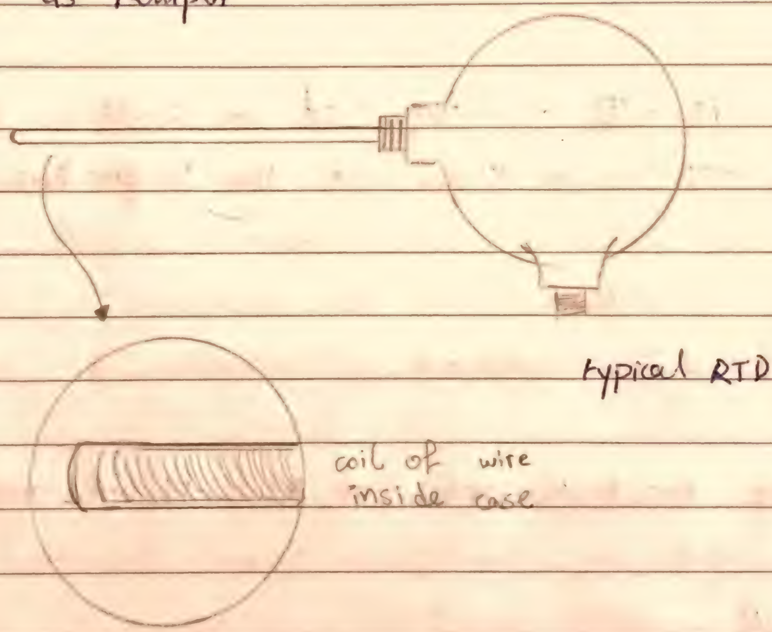
the equation of the system:

Co = v_o * T = v_i * rate * T

$$v_i = \frac{Co}{rate * T}$$

Temperature sensors give an output proportional to temperature. most temperature sensor have positive coefficient (PTC) (desirable) which that the sensor output gose up as the temperature goes up.
Some sensors have negative temperature coefficient (NTC) which means that the output goes down as the temperature goes up.

RTD : Resistance temperature detectors : is a temperature sensor based on the fact that metals increase in resistance as temper



A wire, such a platinum, is wrapped around a ceramic or glass rod (sometimes the wire coil is supported between two ceramic rods).

RTDs are available in different resistance, a common value being : 100Ω. Thus, a 100-Ω platinum (Pt 100 RTD) has resistance of 100Ω at 0°C and has sensitivity of 0.39 Ω/C°

$$R = R_0 + \alpha \Delta T$$

some characteristics

Sensitivity : dependent on its kind

Responce time : (0.5 ~ 5) sec   الزمن الذي يستغرقه الحساس للإستجابة لتغير الحرارة

Range : Platinum (-100°C ~ 650°C)

Nicel (-180 °C ~ 300°C)

Examples:

- A 100-Ω Pt RTD is being used in a system. The present resistance reading is 110Ω. Find the temperature.

$R = 110 - 100 = 10\,\Omega$

$T = \dfrac{10}{0.39} = 25.6\,°C$

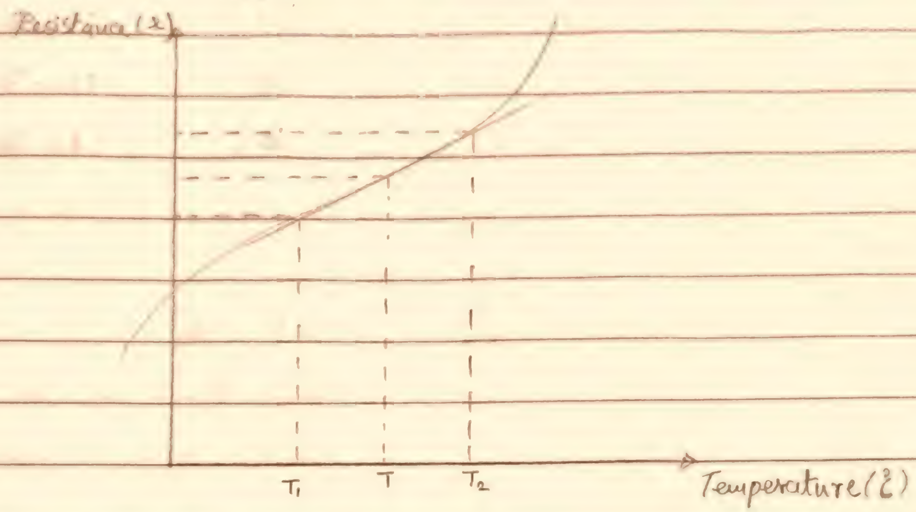
- Find the resistance value of 100Ω Pt of 100Ω at 10°C

$R = 100 + (0.39 * 10)$

$R = 103.9\,°C$

The advantage of RTD is being very accurate and stable. But its disadvantages are low sensitivity, relatively slow responce time, and high cost.

RTD linear approximation



$R(T) = R(T_0) [1 + \alpha_0 \Delta T]$ $\quad T_1 < T < T_2$

resistance at temperature T_0

approximation of resistance at temperature T

$\Delta T = T - T_0$

α_0 = fractional change in resistance per degree

$$\alpha_0 = \frac{1}{R(T_0)} \cdot \frac{R_2 - R_1}{T_2 - T_1}$$

R_2 = resistance at T_2

R_1 = resistance at T_1

Ex:

Find the linear approximation of resistance versus temperature between 60F° to 90°F

T (°F)	R (Ω)
60	106.0
65	107.6
70	109.1
75	110.2
80	111.1
85	111.7
90	112.2

$$\alpha_0 = \frac{1}{R(T_0)} \cdot \frac{R_2 - R_1}{T_2 - T_1}$$

اول قيمة

اخر قيمة

قيمة المقاومة عند درجة الحرارة المتوسطة

$$\alpha_0 = \frac{1}{110.2} \cdot \frac{112.2 - 106.0}{90 - 60} = 1.8753\,m$$

check your answer

$R(60F) = 107.1$ error $= -1\%$

$R(85) = 112.3$ error $= 0.54\%$

RTD Quadratic approximation.

$$R(T) = R(T_0)\left[1 + \alpha_1 \Delta T + \alpha_2 (\Delta T)^2\right]$$

where

$R(T)$ = quadratic approximation of the resistance.

$R(T_0)$ = resistance at T_0

$\Delta T = T - T_0$

α = linear fractional change in resistance with temperature

α_2 = quadratic fractional change in resistance with temperature

Ex:

Find the quadratic approximation resistance versus temperature between 60°F and 90°F

T(F°)	R(Ω)
60	106.0
65	107.6
70	109.1
75	110.2
80	111.1
85	111.7
90	112.2

Solution

$106.0 = 110.2\,[1 + \alpha_1 (60-75) + \alpha_2 (60-75)^2]$

$112.2 = 110.2\,[1 + \alpha_1 (90-75) + \alpha_2 (90-75)^2]$

بحل المعادلتين

$\alpha_1 = 1.8746\ m$

$\alpha_2 = -44.355\ \mu/(F)^2$

check your answer

$R(60) = 106.0\ \Omega$ error = 0%

$R(85) = 111.8\ \Omega$ error = -0.09%

Note the quadratic approximation provides a much better approximation of the resistance versus temperature

2018/6/11 22nd lecture

Thermocouple Tables

tables give the output voltage over a range of temperature in 5°C increments, the reference temperature is 0°C

The temperature in °C and the output in mV

in case the masured voltage does not fall exactly on a table value, we use interpolate

$$T_M = T_L + \left[\frac{T_H - T_L}{V_H - V_L}\right](V_M - V_L)$$

if the termperature does not found

$$V_M = V_L + \left(\frac{V_H - V_L}{T_H - T_L}\right)(T_M - T_L)$$

Ex: A voltage of 23.72 mV is measured with a type k thermocouple at a 0°C reference. Find the temperature of the measurement junction

$V_m = 23.72$ mV does not found in table so we use intrpolate

$$T_M = 570°C + \frac{575 - 570}{(23.84 - 23.63)m}(23.72 - 23.63)m$$

$$T_m = 572.1 °C$$

Ex: Find the voltage of a type J thermocouple with $0°C$ reference if the junction temperature $-172°C$

$$V_H = -7.27m + \frac{-7.12 + 7.27}{-170 + 180}(-172 + 175)$$

$$V_H = -7.18\,mV$$

Change of Table reference

it is possible to use tables with TC (Termocouple) has a different reference temperature by an appropriate shift in the table scale.

يعني أنه في حالة كان TC لديه مرجعية اخرى غير الصفر
فإن قيمة الجهد تساوي

قيمة الجهد عند المرجعية الجديدة = قيمة الجهد عند المرجعية صفر − قيمة الجهد للمرجعية الجديدة عند الصفر

Example $V_{30}(T) = V_0(T) - V_0(30)$